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Development of a laboratory practice for physics introductory courses using a rubric for evaluation by competences

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Abstract. Competence-based education is oriented towards an evaluation model linked to student training, in order to foster the development of abilities to identify, project, solve problems and make decisions. In this context, the rubrics allow obtaining evidence of the acquisition of competences and application of knowledge outside the classroom.
In this work, we present a proposal for the development of a Physics laboratory practice with the use of a rubric for the evaluation by competences in the university field. We want to introduce new assessment methods and identify opportunities to develop skills and evaluate learning through indicators of progress.

1. Introduction
The first rubric dates back to 1912, derived from a study carried out by Noyes, called Scale for the Measurement of Quality in English composition by Young People emerges [1].
The rubric is a shared instrument between professor and students with the required criteria to carry out learning and evaluation tasks. It is a task guide that shows the expectations that students and professors have and share about an activity or several activities, organized in different levels of compliance: from the least acceptable to the exemplary resolution, from what is considered insufficient to excellent [2].
A study about the use of rubrics in Higher Education show that rubrics give reliability and validity to student performance Student self-assessment, self-regulation and understanding of assessment criteria are better enhanced by the use of rubrics [3].
According to UNESCO [4], competence-based education considers contextual aspects such as learning outcomes and performance criteria that imply ensuring know-how, knowing how to live together and knowing how to be. This provides greater integration and knowledge in the actions of students [5]. Olmedo-Torre mentions that the assessment tools most frequently used by academic staff are rubrics [6].
From the formative approach by competences the learning develops the acquisition of basic competences such as team work, the creative and entrepreneur capacity or communicate and relationship capacity [7]. In addition, it allows developing different aspects in the students as it is shown in figure 1.

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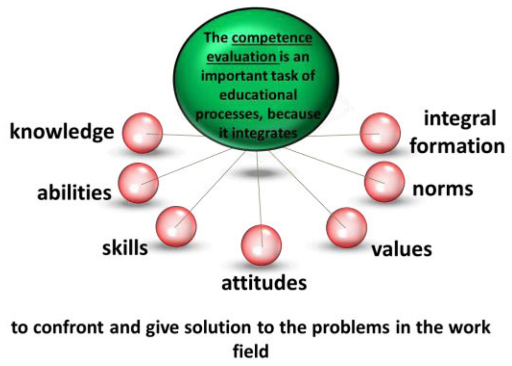

Figure 1. Different aspects from the competence evaluation

The proposals about the evaluation by competences in the university propose an evaluative approach centered in the formative learning and the acquisition of competitions of the students. The evaluation is structured in: intra-group evaluation, which is done within the groups and which affects the work done in different areas (organization, relationship and results) during a group task; inter-group evaluation, which is carried out in the analysis of products from different groups; and the individual evaluation, in which the learning process or product is evaluated. Therefore, the use of strategies that promote peer evaluation enables the acquisition of skills and competences that are necessary for the professional future of students [8].

The purpose of the rubric changes depending on what you want to evaluate. Therefore, they are classified into two types, holistic or global and analytical [2,9,10], as it is shown in figure 2.

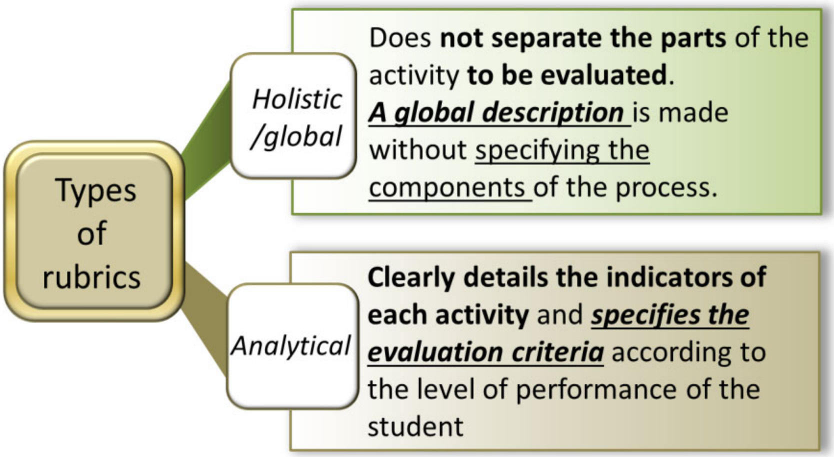

Figure 2. Types of rubrics: holistic and analytical

It is necessary to consider that the use of rubrics benefits both professor and students, but the results depend on the people involved in this process. In this work, we present a proposal for the development of a Physics laboratory practice with the use of a rubric for the evaluation by competences in the university field.

2. Methodology

The Physics laboratory practice "Measurement of the magnetic field of a small magnet" [11] is being made since 2015 by students of the computer engineering degree of the Faculty of Computer Science Engineering at the University of Castilla-La Mancha (UCLM), located in the campus of Albacete, Spain.

For the implementation of this proposal, we will select two study groups, (control and experimental group: A and B) and two physics professor (one for each group), in figure 3 we show the implementation process of the rubric [12].

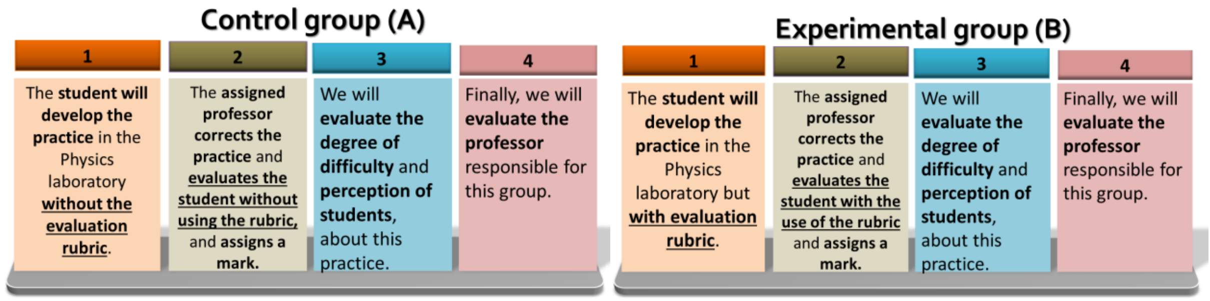

Figure 3. Implementation process of the rubric

After the rubric implementation process, we will analyse the results of both evaluations and the marks obtained by the students of each group, and we will make a comparative analysis to identify the impact generated using rubrics in the evaluation by competences.

3. Results

In this phase, we have developed a laboratory practice with its corresponding evaluation rubric (table 1); at the end of the next course we will have data to evaluate the usefulness of this rubric.

Next, we can see the evaluation rubric of the physics laboratory practice: **Measurement of the magnetic field of a small magnet.**

Objective: Calculate the dependence of the x-component of the magnetic field of a small magnet on the distance using the magnetic sensor that have incorporated the vast majority of "smart" mobile phones, along with an application that has to be previously installed; analyse and reflect on the development of the practice and use of the smartphone in a Physics lab.

The competence components that want to be mobilized, are:
- The distance data to the smartphone and the value of the magnetic field **x(cm**) and **B(μT)**
- Adjustment by least squares **y = mx + b**
- Value of the exponent **n** of the variable x correctly expressed with its error
- μ value, the magnetic moment with its absolute error and units
- Correct realization of the graph **B** versus **x**
- Correct completion of the appropriate logarithmic graph
- Analysis and response to four questions about the smartphone practice

The evidence or results for this practice are:
- Data (values) **x(cm)** and **B(μT)**
- Adjustment by least squares **y = mx + b**
- Value of the exponent **n**
- Value of **μ**
- Graphic **B** vs. **x**
- **Logarithmic** Graphic
- Answers of **4 questions**

Comprehension and observation for data acquisition.
- The experimental data acquired in the laboratory **x(cm)** and **B(μT)**

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Analysis and data processing
- Adjust by least squares **y = mx + b**
- Value of the exponent **n** of the variable x well expressed with its absolute error
- **M value**, with its absolute error and units
- Correct completion of the graph **B** vs. **x**
- Correct completion of the **logarithmic** graph

Reflection to obtain conclusions
- Analysis and answer **four questions** about the Smartphone practice.

Materials:
- A Smartphone that has a magnetic sensor
- An application capable of displaying the three components of the magnetic field measured by the magnetometer, installed on the Smartphone
- A rule that allows measuring in centimetres
- A sheet of paper, A4 size
- A fridge magnet (small and powerful)
- A computer
- Excel Program

Questions about the Lab Session of the Smartphone
- Why do you place your Smartphone towards the North?
- Why must the exponent of the variable x be negative?
- How do you improve this lab session?
- Which is your opinion about the introduction of Smartphones in the Physics lab sessions?

Once the practice has been completed and after having reflected and answered the four questions, it is necessary to draw up a **conclusion that includes**: the impact that the practice has on their previous knowledge, those that have been put in place and those that have been developed to respond to the learning requirements of this activity; in addition, it must be mentioned what has been learned and how it has been learned.

Scale to assess the level reached in each dimension.

- **Level A: Outstanding** = Non-modified (value 10).
- **Level B: Notable** = Suitable with some small observation without modifications (value 8).
- **Level C: Well** = Apt with some observation with modifications (value 6).
- **Level D: Insufficient** = Not suitable with important modifications (value 3).
- **Level E: Very deficient** = Not suitable, complete modification of the activity (value 0) or did not present.

This activity has a value of 10 points, which is the maximum grade of this practice. In table 1, the analytical type rubric is shown for the respective evaluation.

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Table 1. *Evaluation rubric: The Measurement of the Magnetic Field of a Small Magnet*

ASPECT OR CRITERIA TO EVALUATE		**QUALITATIVE/QUANTITATIVE EVALUATION LEVELS**					**OBSERVATIONS**
DIMENSION	**SUBDIMENSION**	**Level E: Very Deficient Grade 0**	**Level D: Insufficient Grade 3**	**Level C: Well Grade 6**	**Level B: Notable Grade 8**	**Level A: Outstanding Grade 10**	
Comprehension and observation to be able to take the data	Data of the variables to measure **x(cm)** and **B(μT)**	The table does not show any of the 16 values of these two variables: or the assignment was not turned in. (0 points)	The table shows the 16 values of these two variables incorrectly. (0.2 points)	The table shows correctly only 5 values of these two variables. (0.6 points)	In the table, only 8 values of these two variables are displayed correctly. (0.8 points)	The table shows the 16 values of these two variables correctly. (1 point)	
Analysis and values calculation.	Adjustment by least squares **y = mx + b**	The value of the adjustment line by least squares **y = mx + b**, is not displayed or the job was not delivered. (0 points)	Correctly displays only 1 of these values: **m, ε_a(m), b, ε_a(b), r** of the adjustment line by least squares **y = mx + b.** (0.6 points)	Correctly shows only 2 of these values: **m, ε_a(m), b, ε_a(b), r** of the adjustment line by least squares **y = mx + b.** (1.2 point)	Correctly shows only 3 of these values **m, ε_a(m), b, ε_a(b), r** of the adjustment line by least squares **y = mx + b.** (1.7 points)	Correctly shows the 5 of these values **m, ε_a(m), b, ε_a(b), r** of the adjustment line by least squares **y = mx + b.** (2 points)	
	Value of the exponent **n**	The value of both the exponent **n** and its corresponding error were obtained, or the assignment was not delivered. (0 points)	Incorrectly obtains the value of the exponent **n**, without calculating the error. (0.4 points)	Correctly obtains the value of the exponent **n**, but miscalculates its error. (0.7 points)	Correctly obtains both the value of the exponent **n** and its error, but expresses them Incorrectly. (0.8 points)	Correctly obtains both the value of the exponent **n**, and its error, and correctly expresses it. (1 point)	
	Value of the magnetic moment **μ**	The value of both the exponent **μ** and its corresponding error were obtained, or the assignment was not delivered. (0 points)	Incorrectly obtains the value of the exponent **μ**, without calculating the error. (0.4 points)	Correctly obtains the value of the exponent **μ**, but miscalculates its error. (0.7 points)	Correctly obtains both the value of the exponent **μ** and its error, but expresses them Incorrectly. (0.8 points)	Correctly obtains both the value of the exponent **μ**, and its error, and correctly expresses it. (1 point)	
	Graph **B vs x**	It does not show the experimental points or the graph, or the assignment was not delivered. (0 points)	Incorrectly shows the experimental points in the graph uniting them by segments. (0.3 points)	Correctly shows the graph without clearly specifying the experimental points. (0.6 points)	Correctly shows the experimental points in the graph, but does not specify the axes. (0.8 points)	Correctly shows the experimental points in the graph, with their corresponding axes. (1 point)	
	Logaríthmic Graph	It does not show the experimental points or the **log** graph, or the assignment was not delivered. (0 points)	Incorrectly shows the experimental points in the **log** graph uniting them by segments. (0.6 points)	Correctly shows the **log** graph without clearly specifying the experimental points. (1.2 point)	Correctly shows the experimental points in the **log** graph, but does not specify the axes. (1.6 points)	Correctly shows the experimental points in the **log** graph, with their corresponding axes. (2 points)	
Reflection to obtain conclusions.	Answer to the four questions	None of the questions are answered, and there is no conclusion, or the assignment was not delivered. (0 points)	Responds specifically only 1 question and the conclusion. (0.5 points)	Responds specifically only 2 questions and the conclusion. (1 point)	Responds specifically only 3 questions and the conclusion. (1.5 points)	Responds specifically the 4 Questions and the conclusion. (2 points)	

The interpretation of the evaluation levels are as follows:

- **Level A: Outstanding** = Non-modified (value 10).
- **Level B: Notable** = Suitable with some small observation without modifications (value 8).
- **Level C: Well** = Apt with some observation with modifications (value 6).
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The implementation of the use of the competence assessment rubric for the development of the practice was carried out as indicated in the methodology.

In figure 4, we can see the development of the practice in the Physics laboratory without the rubric evaluation (control group); figure 5, the data acquisition and, figure 6, development of the practice in the Physics laboratory with the rubric evaluation (experimental group).

Figure 4 Development of the practice in the Physics laboratory without the evaluation rubric (control group)

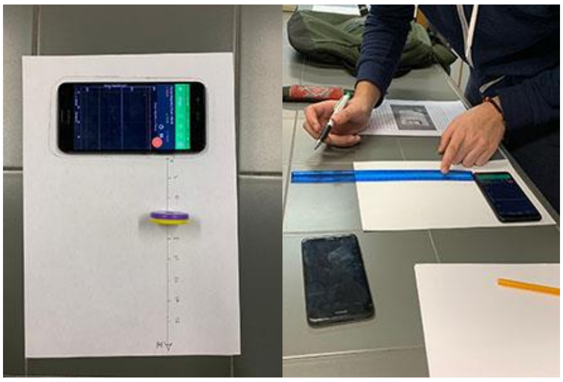

Figure 5. Development of the practice in the Physics laboratory (measurement)

Figure 6. Development of the practice in the Physics laboratory with the evaluation rubric (experimental group)

Once the students concluded the development of the practice, the professor of the subject proceeded with the correction of these; the professor evaluated these practices with and without the use of the rubric for the experimental group and the control group, respectively.

Finally, with the R Studio software, the statistical analysis of the marks obtained by each group was made, the means were obtained and subsequently, a comparison was made through a box diagram (Figure 7).

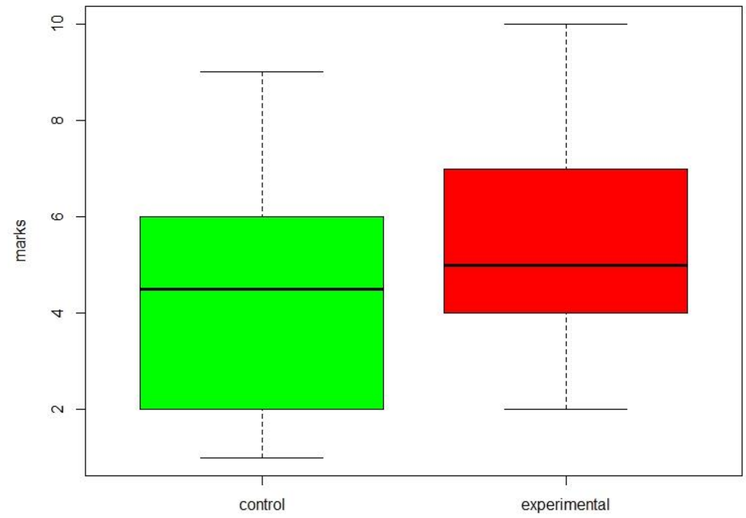

Figure 7. Boxplot with whiskers median marks of control group and experimental group

The mean mark of the control group was 4.6 and the median 4.5, compared to the experimental group, the mean was 5.4 and the median was 5.0. In figure 8, we can see that in the control group the highest mark was 9.0, but 50% of the marks were concentrated in the range of 2.0 to 6.0, marks inside the green box; while, in the experimental group, the highest mark was 10, but 50% of the marks were concentrated in the range of 4.0 to 6.5. These results indicate that the use of rubrics contributes to the increase of marks.

On the other hand, we can see that this increase is not high. We consider that this may be due to the difficulty of the students to understand this new way of evaluating and, also, because it is a new instrument. We will continue working with other similar groups, control and experimental groups, for the development of another practice, and other professors of this subject to obtain more data that allow us to compare and obtain new conclusions.

4. Conclusion and discussion

We have implemented evaluation rubrics by competences, with students in computer engineering degree of the Faculty of Computer Science Engineering at University of Castilla-La Mancha (UCLM), located in the campus of Albacete, Spain.

With the results obtained, we can be affirmed that the students' marks have increased, however, this increase is moderate, around 15%. Therefore, it can be concluded that the application of rubrics by competences can be a useful tool for students when developing their practices and, also, for the professor when they have to evaluate them. But as it is an instrument that is unknown on the part of the students, therefore, the interest is little, and they only want to approve with the minimum effort. However, there is also a small percentage (less than 25%) that aim to obtain the highest mark.

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Therefore, we have decided to continue with this work, using this type of instrument in another laboratory practice, with two other new groups and another professor, to have more data that will allow us to show if it is useful or not the use of rubrics.

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